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Specification and Drawings as originally filed, with Application for Patent Serial No: **2,327,862**, on December 6, 2000, by **JDS UNIPHASE INC.**, assignee of Thomas Ducellier and Andrew Tsiboulia, for "Optical Switch ".

S. Grégoire

Agent certificateur/Certifying Officer

October 29, 2001

Date

Optical switch

What is disclosed is:
An optical switch comprising:

- optical ports to couple light in and out of the switch
- at least an array of deflection means with an hole in it

arranged such that light coming to or from the optical ports passes through the hole in the array of deflection means.

In particular:
The array of deflection means can be an array of micromirrors tilting in two perpendicular directions having an hole in its middle.

The optical ports can consist of optical fibers coupled to collimator lenses.

The arrangement to provide that all light passes through the hole in the array of deflection means could be an optical element having power.

Preferred embodiement:
In the preferred embodiement, the input fiber array is coupled to an input array of microlenses. These beams travel through a first input relay lens that forces all the light to pass through a hole in the 2nd MEMS array. A central lens, whose focal length is approximatively the Rayleigh range of the beam passing through the hole re-image the input beams on the first micromirror MEMS array. Based on the deflection angle of these micromirrors, the light reaches the micromirrors on the 2nd MEMS array after passing through the central lens. Then the micromirrors on the 2nd MEMS array are oriented such that all light travels essentially parallel to the optical axis of the central lens. After passing through the central lens again, all light passes through the hole in the 1st MEMS array, and is re-images through the 2nd output relay lens onto a microlens array that couples light in the output fibers.

OPTICAL SWITCH

Field of the Invention

The present invention relates to the field of optical switches.

Background of the Invention

Optical matrix switches are commonly used in communications systems for transmitting voice, video and data signals. Generally, optical matrix switches include multiple input and/or output ports and have the ability to connect, for purposes of signal transfer, any input port/output port combination, and preferably, for N x M switching applications, to allow for multiple connections at one time. At each port, optical signals are transmitted and/or received via an end of an optical waveguide. The waveguide ends of the input and output ports are optically connected across a switch interface. In this regard, for example, the input and output waveguide ends can be physically located on opposite sides of a switch interface for direct or folded optical pathway communication therebetween, in side-by-side matrices on the same physical side of a switch interface facing a mirror, or they can be interspersed in a single matrix arrangement facing a mirror.

Establishing a connection between a given input port and a given output port, involves configuring an optical pathway across the switch interface between the input ports and the output ports. One way to configure the optical pathway is by moving or bending optical fibers using, for example, piezoelectric benders. The benders associated with fibers to be connected bend the fibers so that signals from the fibers are targeted at one another so as to form the desired optical connection across the switch interface. The amount of bending is controlled based on the electrical signal applied to the benders. By appropriate arrangement of benders, two-dimensional targeting control can be effected. Another way of configuring the optical path between an input port and an output port involves the use of one or more moveable mirrors interposed between the input and

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output ports. In this case, the waveguide ends remain stationary and the mirrors are used for switching. The mirrors can allow for two-dimensional targeting to optically connect any of the input port fibers to any of the output port fibers.

An important consideration in switch design is minimizing switch size for a given number of input and output ports that are serviced, i.e., increasing the packing density of ports and beam directing units. It has been recognized that greater packing density can be achieved, particularly in the case of a movable mirror-based beam directing unit, by folding the optical path between the fiber and the movable mirror and/or between the movable mirror and the switch interface. Such a compact optical matrix switch is disclosed in U.S. Patent No. 6,097,860. In addition, further compactness advantages are achieved therein by positioning control signal sources outside of the fiber array and, preferably, at positions within the folded optical path selected to reduce the required size of the optics path.

Current switch design continuously endeavors to accommodate more fibers in smaller switches.

It is an object of this invention to provide a compact optical switch.

Another object of this invention is to provide a compact but large optical crossconnect arrangement.

Summary of the Invention

In accordance with the invention there is provided.

Brief Description of the Drawings

Exemplary embodiments of the invention will now be described in conjunction with the drawings in which:

Fig. 1

Fig. 12

Detailed Description of the Invention

Fig. 12 shows a large optical cross-connect arrangement 1200 in accordance with the present invention. Optical switch 1200 is scalable to 4000x4000 and is based on arrays of two-dimensional tilt mirrors 1210 and 1220 and ATO lens 1230. An input fiber bundle 1240 is shown on the left hand side of Fig. 12. An input micro-lens array 1250 is placed at an end face of the input fiber bundle 1240 having one micro-lens centered on an optical axis of each fiber. An input relay lens 1260 is provided between the micro-lens array 1250 and a first MEMS chip 1210 having an array of two-dimensional tilt mirrors/micro mirrors. The distance between the input micro-lens array 1250 and the input relay lens 1260 and the input relay lens 1260 and the first MEMS chip 1210 corresponds to a focal length of the input relay lens 1260. This input relay lens 1260 sends a beam of light incident thereon through a hole 1270 in the first MEMS chip 1210. The first MEMS chip 1210 is followed by an ATO lens 1230, i.e. an element having optical power whose focal length corresponds to the near zone length (multi mode) or Rayleigh range (single mode) of the beam incident on the 2D tilt mirrors, and a second MEMS chip array 1220 having an array of two-dimensional tilt mirrors/micro mirrors and a hole 1280 disposed thereon. Both, the first MEMS chip 1210 and the second MEMS chip 1220 are arranged at a distance from the ATO lens 1230 which corresponds to the focal length of ATO lens 1230. The second MEMS chip 1220 is followed by an output relay lens 1290 which focuses the light to an output micro-lens array 1300 provided at an end face of an output fiber bundle 1310 having one micro-lens centered on an optical axis of each fiber. The distance between the second MEMS chip 1220 and the

output relay lens 1290 and the output relay lens 1290 and the output micro-lens array corresponds to a focal length of the output relay lens 1290. All components are arranged along an optical axis OA. Such an arrangement provides for an even more compact design of an optical switch in accordance with the present invention, and lessens aberration effects of the lens. In order to demonstrate more clearly how optical switch 1200 functions, an exemplary beam of light L is traced along an optical path A to H through switch 1200. The beam L exits an input fiber at point A at an end face thereof having a micro-lens disposed thereon. The beam L propagates parallel to the optical axis OA until it reaches point B on the input relay lens 1260. Input relay lens 1260 sends beam L at an angle to the optical axis OA to point C on the ATO lens 1230 through the hole 1270 in the first MEMS chip 1210. The ATO lens 1230 sends beam L parallel to the optical axis OA to point D on one of the micro-mirrors on the second MEMS chip 1220. The mirror on the second MEMS chip 1220 switches beam L to point E on one of the micro-mirrors on the first MEMS chip 1210 after passing through the ATO lens 1230. The micro-mirror on the first MEMS chip 1210 sends the light back to point F on the ATO lens 1230 parallel to the optical axis OA and then at an angle to the optical axis OA to point G through hole 1280 in the second MEMS chip 1220. The output relay lens 1290 collects the beam of light L coming from hole 1280 in the second MEMS chip 1220 and images it on the output micro-lens array 1300. An output fiber in the output fiber bundle 1310 collects beam L from the output micro-lens array 1300. It is apparent that this switch also functions in reverse, i.e. the output fiber bundle then functions as the input fiber bundle and so forth.

Advantageously, this embodiment of an optical switch in accordance with the present invention provides for the use of high fill factor arrays of two-dimensionally tiltable micro-mirrors to redirect light beams while providing a very compact switch which lessens aberration effects of the lens. The linear arrangement of all components along the optical axis OA affords a very compact design of switch 1200. A further factor in affording a compact switch 1200 is that small components can be used in this switch because of the beam geometry.

In order to obtain an aggregate information about the alignment of optical switch 1200, multiplexed error signals are measured at the input and output ports

Numerous other embodiments can be envisaged without departing from the spirit and scope of the invention.

Claims

What is claimed is:

1. An optical switch comprising:

at least one input port for launching a beam of light into the optical switch;

at least two output ports for selectively receiving the beam of light;

a first plurality of independently moveable deflectors each for selecting an optical path to direct the beam of light to a selected one of the at least two output ports, said first plurality of independently moveable deflectors being arranged so as to have a first passage therebetween for allowing the beam of light to pass therethrough; and

a deflector arranged for receiving the beam of light passed through the first passage and for deflecting the beam of light to any one of the first plurality of independently moveable deflectors and for receiving the beam of light from any one of the first plurality of independently moveable deflectors and for deflecting it back through the first passage such that a selected one of the at least two output ports receives the beam of light.

2. The optical switch as defined in claim 1 wherein the at least one input port, the at least two output ports, the first plurality of independently moveable deflectors, and the deflector are arranged in-line.

3. The optical switch as defined in claim 2 wherein the first plurality of independently moveable deflectors comprises an array of micro-mirrors.

4. The optical switch as defined in claim 3 wherein the array of micro-mirrors is one of a linear, rectangular, and radial array.

5. The optical switch as defined in claim 1, wherein the deflector is a second plurality of independently moveable deflectors arranged so as to have a second passage therebetween for allowing the beam of light to pass therethrough.

6. An optical switch comprising:

at least one input port for launching a beam of light into the optical switch;

at least two output ports for selectively receiving the beam of light;

a first plurality of independently moveable deflectors arranged so as to have a first passage therebetween for allowing the beam of light from the at least one input port to pass therethrough; and

a second plurality of independently moveable deflectors arranged so as to have a second passage therebetween for allowing the beam of light to pass therethrough to any one of the at least two output ports, said second plurality of independently moveable deflectors being arranged so as to receive the beam of light that passed through the first passage, and

wherein a switching is carried out by the first and second plurality of independently moveable deflectors.

7. The optical switch as defined in claim 5 wherein the at least one input port, the at least two output ports, the first plurality of independently moveable deflectors, and the second plurality of independently moveable deflectors are arranged in-line.

8. The optical switch as defined in claim 6 further including an in-line first lens for receiving the beam of light from the at least one input port and for directing the beam of light through the first passage, the first lens being arranged between the at least one input port and the first plurality of independently moveable deflectors.

9. The optical switch as defined in claim 8 wherein a distance between the at least one input port and the first lens and the first lens and the first plurality of independently moveable deflectors is approximately equal to the focal length of the first lens

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10. The optical switch as defined in claim 8 further including an in-line second lens for receiving the beam of light from the second passage and for directing the beam of light to a selected one of the at least two output ports, the second lens being arranged between the second plurality of independently moveable deflectors and the at least two output ports.

11. The optical switch as defined in claim 6 further including an element having optical power and having a focal length approximately equal to the Rayleigh range of the beam of light incident thereon, the element having optical power being arranged between the first plurality of independently moveable deflectors and the second plurality of independently moveable deflectors and wherein a distance between the first plurality of independently moveable deflectors and the element having optical power and the element having optical power and the second plurality of independently moveable deflectors is approximately equal to the focal length of the element having optical power.

12. The optical switch as defined in claim 11 wherein the element having optical power is a lens.

13. The optical switch as defined in claim 6 wherein the first plurality of independently moveable deflectors and the second plurality of independently moveable deflectors comprises an array of micro-mirrors.

14. The optical switch as defined in claim 13 wherein the array of micro-mirrors is one of a linear, rectangular, and radial array.

15. The optical switch as defined in claim 6 further including a micro-lens disposed at an end face of a first waveguide at the at least one input port.

16. The optical switch as defined in claim 15 further including an array of micro-lenses at an end face of at least two waveguides at the at least two output ports.

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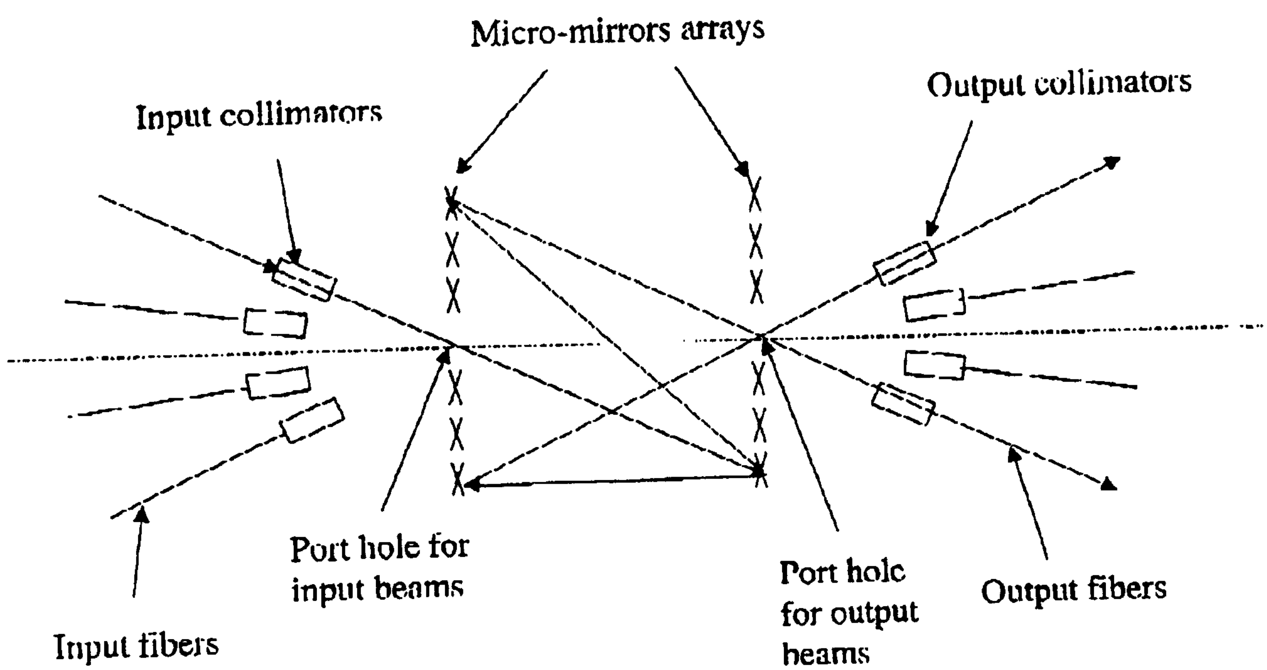
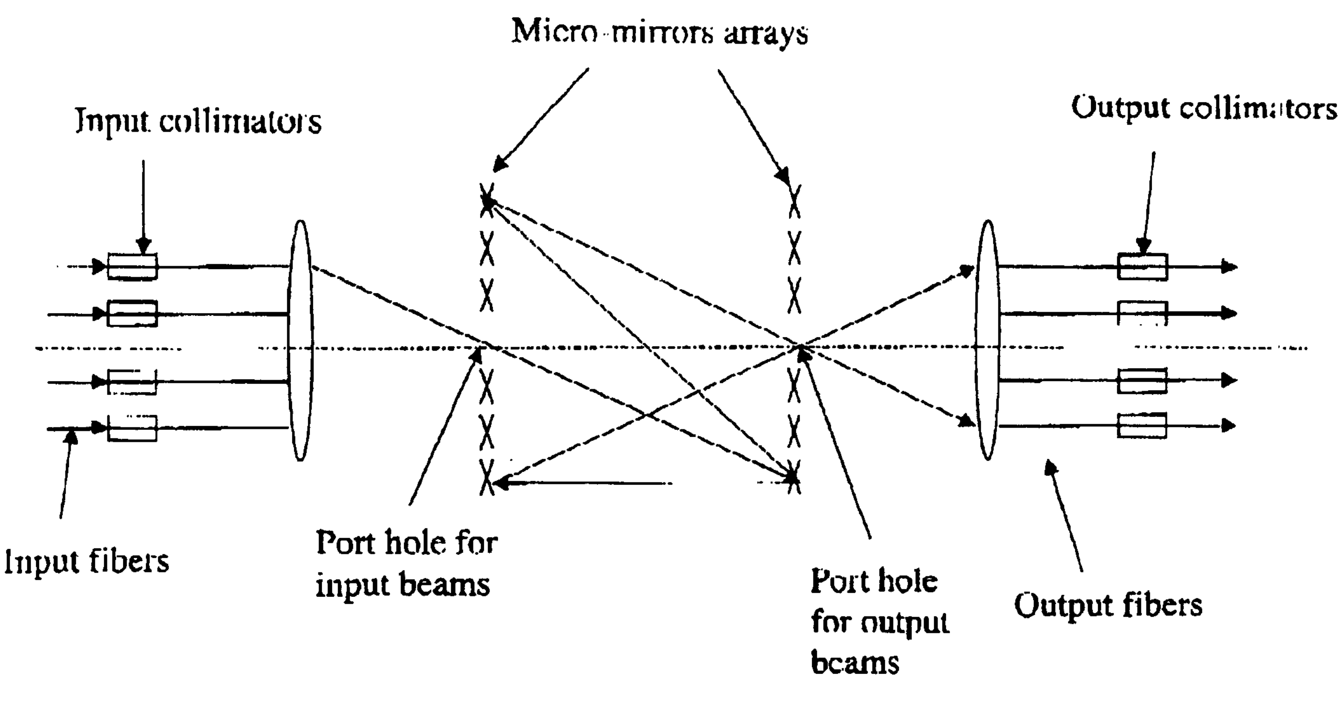
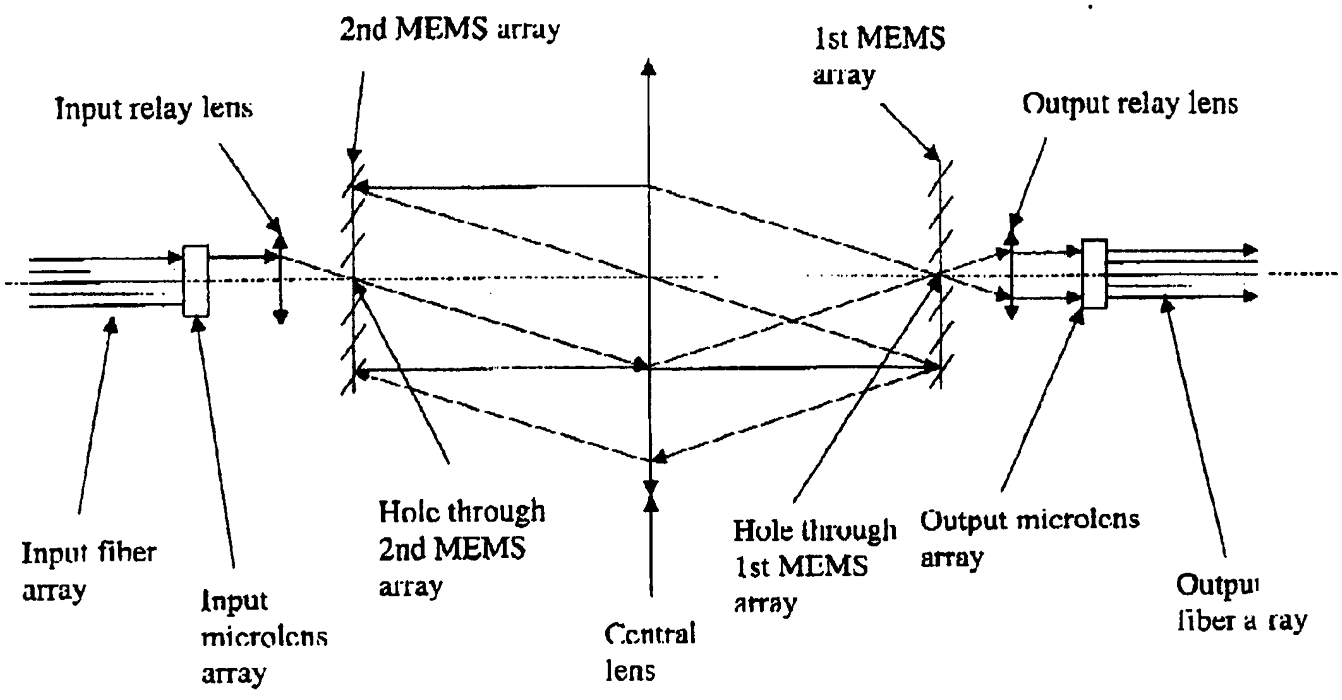


Micro-mirrors arrays
Input collimators
Output collimators
Port hole for input beams
Port hole for output beams
Output fibers
Input fibers


Micro-mirrors arrays
Input collimators
Output collimators
Input fibers
Port hole for input beams
Port hole for output beams
Output fibers


2nd MEMS array
1st MEMS array
Input relay lens
Output relay lens
Input fiber array
Input microlens array
Hole through 2nd MEMS array
Central lens
Hole through 1st MEMS array
Output microlens array
Output fiber a ray

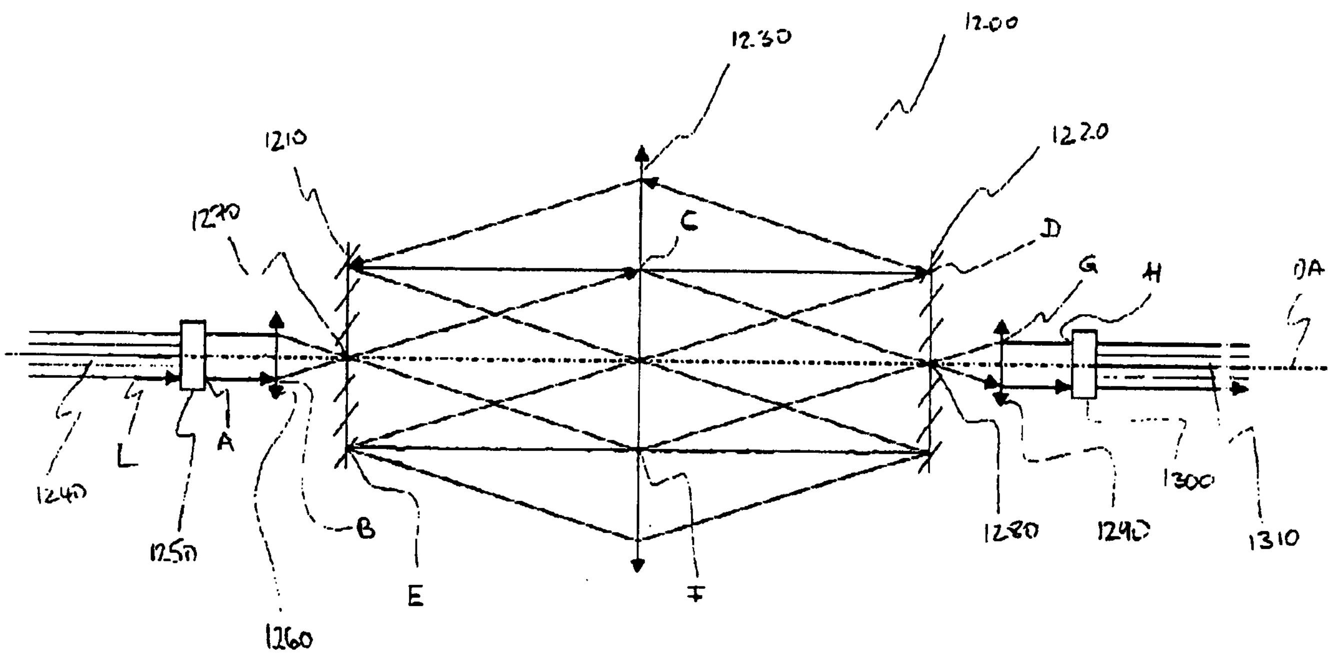

1200
1230
1210
1220
1270
C
D
G
H
OA
1240
L
A
1250
1260
B
E
F
1280
1290
1300
1310

Fig. 12